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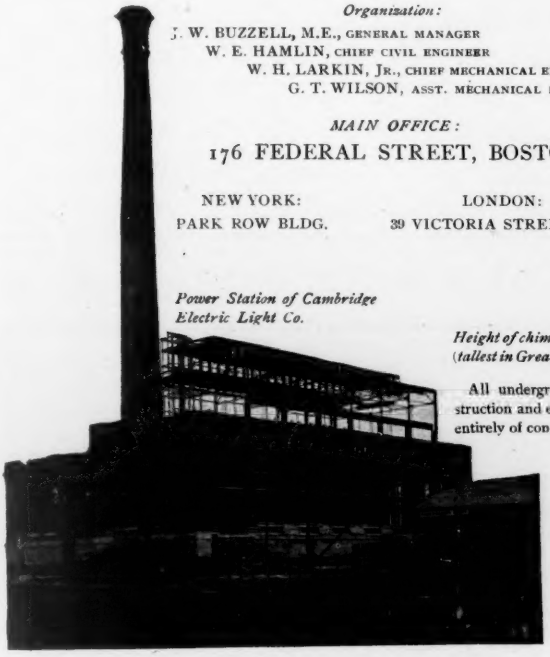

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THE TECHNOLOGY QUARTERLY

AND

PROCEEDINGS OF THE SOCIETY OF ARTS

Edited by ROBERT P. BIGELOW, PH D.

THE TECHNOLOGY QUARTERLY is an illustrated magazine published by the MASSACHUSETTS INSTITUTE OF TECHNOLOGY. It is devoted to original articles upon various subjects in **Architecture, Civil Engineering, Mechanical Engineering, Electrical Engineering, Physics, Chemistry, Biology, Bacteriology, Mining** and **Metallurgy,** or, in general, the **Sciences** and their applications to the **Useful Arts.**

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AND

PROCEEDINGS OF THE SOCIETY OF ARTS.

VOL. XVI MARCH, 1903 NO. 1

PROCEEDINGS OF THE SOCIETY OF ARTS.

FORTY-FIRST YEAR, 1902–1903.

BOSTON, October 9, 1902.

THE 569th regular meeting of the SOCIETY OF ARTS was held on Thursday evening, October 9th, in the Lowell Building, President Pritchett presiding. Three hundred persons were present. The minutes of the last meeting were read and approved. The resignation of Dr. G. V. Wendell having been received and accepted, the Executive Committee proposed the nomination of Dr. J. F. Norris for the office of Secretary for the year 1902–1903. On the motion of Mr. Munroe, it was voted to instruct the Secretary to cast the ballot of the Society for Dr. Norris.

The address of the evening was then delivered by Professor Louis Duncan, Director of the Department of Electrical Engineering of the Institute, on "Long Distance Electric Railroading." The address will appear in the next number of the TECHNOLOGY QUARTERLY.[1]

[1] TECHNOLOGY QUARTERLY, Vol. XV, No. 4, Dec., 1902, pp. 317–325.

BOSTON, October 23, 1902.

The 570th regular meeting of the SOCIETY OF ARTS was held on Thursday evening, October 23d, in Room 22, Walker Building, Professor Niles in the chair. One hundred and fifty persons were present. The minutes of the previous meeting were read and approved. The following named gentlemen were elected Associate Members of the Society: Mr. Thomas M. Roberts, General Electric Company, Mr. Hezekiah Bissell, Chief Engineer, Boston & Maine Railroad.

Mr. John G. Jack, of the Arnold Arboretum, addressed the Society on "The Identification of Our Woody Plants in Winter."

A vote of thanks was tendered to the speaker, and the meeting adjourned.

BOSTON, November 13, 1902.

The 571st regular meeting of the SOCIETY OF ARTS was held on Thursday evening, November 13, in Room 22, Walker Building, ninety-five persons being present. Professor Clifford presided. After the minutes of the previous meeting were read and approved, the following paper was presented, by title, "Some Notes on Several Types of Mantles for Incandescent Gas Burners," by Mr. William Lincoln Smith. Mr. George H. Bartlett, Principal of the Massachusetts Normal Art School, then addressed the Society on "The Art of Lithography." The technical side of the art was fully discussed and all the materials employed in the process were shown and their use explained. A large number of unusually beautiful lithographs were exhibited. A vote of thanks was tendered the speaker, and the meeting adjourned.

BOSTON, November 28, 1902.

The 572d regular meeting of the SOCIETY OF ARTS was held on Friday evening, November 28th, in Room 22, Walker Building, Professor Peabody in the chair. Three hundred and twenty persons were present. The minutes of the previous meeting were read and approved. Mr. W. Starling Burgess then addressed the Society on "The Designing of Small Racing Yachts." The lecture was illustrated with lantern slides, and a number of models were shown. A vote of thanks was tendered to the speaker, and the meeting adjourned.

BOSTON, December 11, 1902.

The 573d regular meeting of the SOCIETY OF ARTS was held on Thursday evening, December 11th, in Room 22, Walker Building, Professor Talbot in the chair. One hundred and seventy-five persons were present. After the minutes of the previous meeting were read and approved, Professor R. W. Wood of Johns Hopkins University addressed the Society on "A Substance with Remarkable Optical Properties and a Screen Transparent to Ultra-violet Light Only." Professor Wood also gave an account of his diffraction process for color photography. The lecture was illustrated with lantern slides, and a number of experiments were shown. A vote of thanks was tendered the speaker, and the meeting adjourned.

BOSTON, January 8, 1903.

The 574th regular meeting of the SOCIETY OF ARTS was held in Room 22, Walker Building, on Thursday evening, January 8th, one hundred and fifty persons being present. President Pritchett presided. After the minutes of the previous meeting had been read and approved, Mr. S. K. Humphrey was elected to Associate Membership in the Society.

Mr. O. H. Tittmann, Superintendent of the Uuited States Coast and Geodetic Survey, then addressed the Society on "The Coast Survey and Its Work." A vote of thanks was tendered the speaker, and the meeting adjourned.

JAMES F. NORRIS, *Secretary.*

CONTRIBUTIONS FROM THE METALLOGRAPHICAL LABORATORY OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

A STUDY OF THE RELATIONS BETWEEN THE MICRO-STRUCTURE, THE HEAT TREATMENT, AND THE PHYSICAL PROPERTIES OF AXLE STEEL.

BY HENRY FAY, A. W. HIGGINS, AND F. W. COBURN.

THIS investigation was undertaken with the idea of studying the physical properties of some steel such as is used in the manufacture of axles, and the influence of varying heat treatment upon the strength, ductility, and microstructure. General laws have been established by Chernoff[1] and Brinnell[2] in regard to the relations between heat treatment and structure which show an intimate relationship between the structure as shown in the fracture, and the temperature to which the material has been heated. Chernoff clearly observed the methods necessary to prevent coarse crystallization and stated the color temperatures at which the material must be worked in order to obtain the most satisfactory results. Crystalline structure, according to him, was prevented by heating the ingot to a cherry red, at which temperature a fine-grained and strong product was produced; by hammering at a high temperature and continuing the work down to a certain point, which varied with different steels; and by rapid cooling. The point at which these changes are produced is the lower, the higher the carbon of the steel.

Brinnell practically reaches identical conclusions, but he goes further and connects the change of coarse-grained material into fine

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[1] The Structure of Cast Steel Ingots. Proc. Inst. of Mech. Eng., January, 1880; translated from the Russian by W. Anderson. The Manufacture of Steel and the Mode of Working It. Proc. Inst. of Mech. Eng., April, 1880; translated by W. Anderson.

[2] The Changes in the Texture of Steel on Heating and on Cooling. Abstracted in J. Iron and Steel Inst., 1886, No. I, 365.

with the transition of hardening carbon into cement carbon. The transition point he found to vary with the rate of heating or cooling. In the transformation of hardening into cement carbon, rapid cooling from a high temperature lowered this transition point to a lower temperature than it would be if the ingot were allowed to cool slowly from the same temperature. He further points out the relations between the size of the grains and the temperature, the coarsest being obtained at the highest temperature, and the structure remains coarse whether the material is cooled rapidly or slowly from this temperature.

These investigations of Brinnell and Chernoff have been the landmarks from which subsequent investigators have taken their cue. For the most part these results have been verified and confirmed by others. Osmond, Howe, Sauveur, and others have published results in regard to steels containing particular percentages of carbon, and have shown the relation between the heat treatment of these steels and their microstructure.

An apparent exception to the confirmation of these generalizations is the work of Stead[1] on very low carbon steels. The results of his experiments show that in carbonless pure irons or steels the grains increase in size slowly at 500°, and more rapidly at from 650° to 750°, and that it is possible by heating at 700° for a few hours to develop granular masses of exceeding coarseness. At 900° the granules again become small, and heating to 1,200° does not change them. This is an exception to the general laws established by Brinnell, Chernoff, and others, but it must be remembered that the work of Stead was carried on with nearly pure irons, and it is not improbable, as he has shown, that the gases of the furnace have something to do with this peculiar effect.

Various systematic researches have been carried on with steels containing varying amounts of carbon, all of which seemed to confirm the general laws as enunciated by Chernoff and Brinnell. There can hardly be any doubt that there is a very close relationship existing between the properties of any particular steel and the temperature to which it has been heated. In order to establish these relations for a steel such as may be used for axles, we selected a material of the following composition:

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[1] J. Iron and Steel Inst., 1898., No. I., 145.

Carbon . . .	0.41	percent.
Manganese . .	0.58	"
Silicon . . .	0.023	"
Sulphur . . .	0.034	"
Phosphorus . .	0.037	"

This material is technically known as "machinery steel," and is used for a great variety of purposes. The specimens used were in the form of bars 18 inches long and $1\frac{1}{2}$ inches in diameter. We wish to express our indebtedness to the Midvale Steel Co. for so kindly furnishing this material.

The heat treatment of these bars was carried on in an electrically heated furnace similar to the one used by Fay and Badlam[1] in their work on low carbon steel. The current was taken from the 110-volt circuit and was used in series with a German silver rheostat. For delicate adjustment a second rheostat was sometimes used.

Temperatures were measured by a Le Chatelier thermo-electric pyrometer. As our furnace was used in connection with two similar furnaces, the lead wires from each passing to the galvanometer were so arranged that the temperature of any one of the three furnaces could be read by closing a switch connecting that furnace with the galvanometer. The junction was held in place by an iron tube passing through the plug which closed the furnace, and was so arranged that when the furnace was closed, the end of the junction rested within a quarter of an inch of the middle part of the bar being heated. The pyrometer was calibrated against boiling water, boiling sulphur, freezing aluminium, and freezing gold.

Before subjecting any of the bars to heat treatment, the critical points of the steel were determined. Two cross sections were cut, one inch in length. Between these clean surfaces the junction was laid, and the two pieces were then bound together by means of an iron wire. The specimen was then heated in an air blast furnace to about 1000° and readings were made on the galvanometer scale during the cooling. It will be seen from Figure 1, in which temperatures are plotted as ordinates and time in seconds as abscissæ, that the Ar_1 point is very well marked at 670°, but the $Ar_{3.2}$ point is not so well developed at 745°.

[1] Tech. Quart., **13**, 295.

The bars were divided into three series, and each series subjected to a similar heat treatment. Bars 1 to 4 inclusive were heated respectively to 700°, 800°, 900°, and 1,000°, held at the respective temperature for four hours, and cooled in the furnace. Numbers 5 to 9 inclusive were heated respectively to 650°, 700°, 800°, 900° and 1,000°, removed from the furnace when the proper temperature was attained and allowed to cool in the air. Bars 10 to 16 inclusive were allowed to cool in the furnace, after being heated respectively to 650°, 700°, 750°, 800°, 900°, 970°, and 1,000°. In

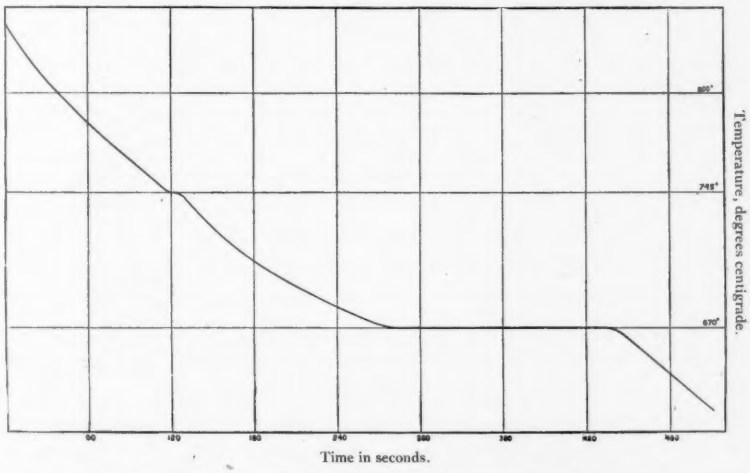


FIG. 1.—CURVE OF COOLING, SHOWING CRITICAL POINTS.

each case the bar was put in the furnace cold and was brought slowly to the required temperature. The temperatures could be regulated almost perfectly by slightly changing the outside resistance. The rate of heating in each case was made as uniform as possible. Where bars were allowed to cool in the furnace, the time of passing from the maximum to room temperature varied from 12 to 18 hours.

For the mechanical tests each specimen was turned down at each end for a distance of 4 inches to $1\frac{3}{8}$ inches in diameter and the central part of 10 inches was turned to a diameter of 1 inch. A 50-ton Olsen machine run by an electric motor furnished the means of breaking the specimens, and could be run at variable speeds.

Slow speed was used and readings of the micrometer were taken at intervals, beginning at 2,000 pounds load.

Specimens for microscopical examination were cut from the shoulder of the broken bar. They were polished to a mirror surface, and then etched by rubbing over a chamois-covered block on which was some rouge and a very dilute ammonium nitrate solution. In some cases this means of etching did not produce enough contrast in the constituents for photographic purposes and this was accomplished by dipping the specimen momentarily in nitric acid and rapidly washing in running water.

Discussion of Results.

The results of the various tests are shown in Table No. I. and by the various curves showing graphically the values for tensile strength, elastic limit, elongation, and reduction of area. The original steel gave a higher tensile strength than any of the other bars. Its microstructure, Figure 4, showed a very uniform distribution of ferrite and pearlite, and gave the suggestion of having been worked to a fairly low temperature. That the original steel showed higher tensile strength than any of the other specimens is perfectly natural. It was probably worked through that interval where crystallization usually takes place on slow cooling, viz., from 1,000° to Ar_1. This work performed on the material in rolling it into round bars prevented crystallization, and it was probably allowed to cool without being worked from Ar_1, which would be the best condition for producing good material. Any heat treatment above Ar_1 would of course destroy this structure, and consequently all results are only relative to those obtained on the original specimen. In Series A, in which the bars were held at varying temperatures for four hours in the furnace, bar No. 1, heated approximately to Ac_1, did not show great change either in physical properties or in microstructure. In bar No. 2, heated to 800° for four hours, there was a considerable falling off in tensile strength and elastic limit, and the microstructure began to show signs of diffusion which became more marked in the specimen heated to 900°. In No. 3 there was still further reduction of the tensile strength, accompanied by reduction in the elongation and increase in the contraction of area. The microstructure, Figure 7, showed a peculiar appearance in which there was very little distinc-

TABLE I. SHOWING TEMPERATURE OF HEATING, METHOD OF COOLING, AND PHYSICAL PROPERTIES.

NUMBER OF SPECIMEN.		TEMPERATURE OF HEATING, DEGREES CENTIGRADE.	MANNER OF COOLING.	TENSILE STRENGTH, LBS. PER SQ. INCH.	ELASTIC LIMIT, LBS. PER SQ. INCH.	ELONGATION IN 8 INCHES.	CONTRACTION IN AREA, PERCENT.	REMARKS ON MICROSTRUCTURE.
1		700	Held 4 hours at maximum. Cooled in Furnace.	93,000	49,600	18.9	42.0	
2	A	800	"	86,100	42,500	18.7	46.3	
3		900	"	80,500	42,700	17.5	52.0	Blurred.
4		1000	"	84,200	41,860	20.5	39.0	Dense masses of pearlite and ferrite.
5		650	Cooled in Air.	94,690	45,230	19.0	38.0	Similar to original.
6		700	"	91,280	44,570	19.9	40.4	Similar to original.
7	B	800	"	91,020	50,970	21.0	46.5	Fine structure.
8		900	"	91,720	48,490	13.0	27.0	Blurred.
9		1000	"	96,510	47,110	17.0	35.5	Large grains of pearlite.
10		650	Cooled in Furnace.	92,050	43,600	18.5	38.5	Similar to original.
11		700	"	91,180	44,390	17.0	39.7	
12		750	"	82,950	36,950	17.0	48.0	
13	C	800	"	86,580	39,500	17.0	46.0	Shows signs of blurred structure.
14		900	"	83,180	40,340	20.1	32.5	Blurred.
15		970	"	86,520	37,290	19.0	32.0	Large area of pearlite.
16		1000	"	78,270	34,570	19.0	38.0	
Original		——	——	95,500	47,000	20.4	37.0	

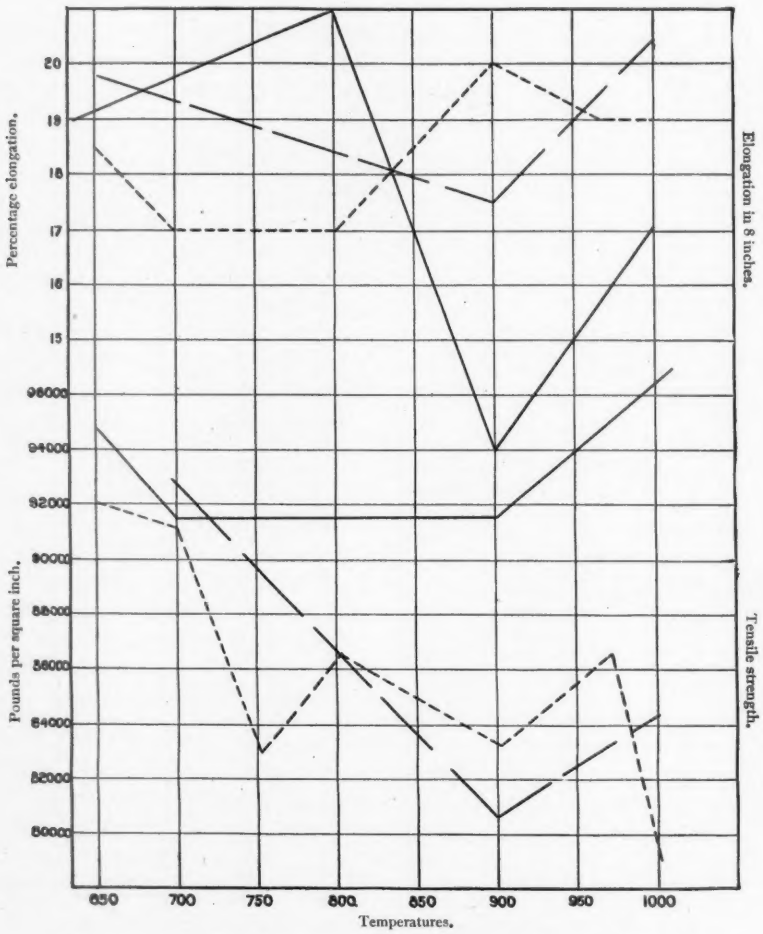


FIG. 2.—GRAPHICAL REPRESENTATION OF RESULTS GIVEN IN TABLE I.

Series A. Long dash line. Bars held at maximum and cooled in furnace.
Series B. Continuous line. Bars cooled in air.
Series C. Dotted line. Bars heated to maximum and cooled in furnace.

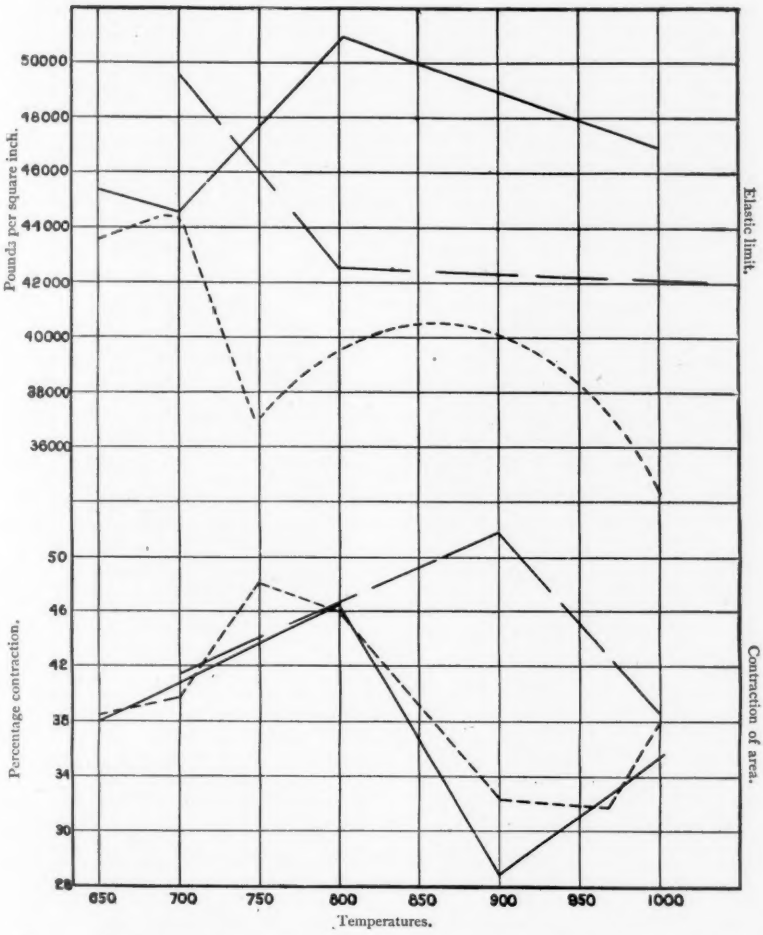


FIG. 3. — GRAPHICAL REPRESENTATION OF RESULTS GIVEN IN TABLE I. — Continued.

Series A. Long dash line.
Series B. Continuous line.
Series C. Dotted line.

tion between the ferrite and pearlite, which would seem to indicate that complete diffusion had taken place at this temperature and that there had not been the subsequent readjustment between the ferrite and pearlite. Specimens 8 and 14, Figures 10 and 13, show this same peculiarity. It does not seem so surprising that readjustment had not taken place in the bar which was allowed to cool in the air, but for those which cooled in the furnace there would seem to be plenty of time for the redistribution of the constituents, ferrite and pearlite. This phenomenon has been observed previously by Göransson[1] and remarked upon by Howe. The material in which it was noticed was in a hyper-eutectic steel containing 1.2 per cent. of carbon.

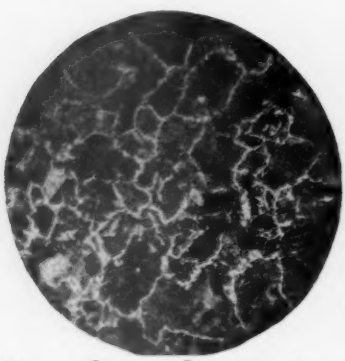


FIG. 4.—ORIGINAL SPECIMEN. × 70.

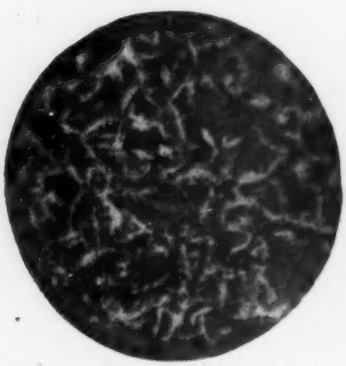


FIG. 5.—SPECIMEN NO. 1. × 70.
Held 4 hours at 700° and cooled in furnace.

That this is a diffusion process seems to be indicated further by the appearance of specimens 4, 9, 15, and 16, Figures 8, 11, 14, and 15, in which it will be observed that the ferrite and pearlite have begun to segregate in separate masses. In specimen No. 9, this segregation seems to be shown in the process of taking place. The small patches of pearlite seem to be diffusing into the larger areas. This particular phase of the problem will be dealt with in detail when considering that particular specimen.

In bar No. 4 of the series heated four hours, the microstructure shows dense masses of segregated pearlite, this structure being characteristic of all of the pieces heated to 1,000°. The tensile strength

[1] Trans. Am. Inst. Min. Eng., 1902.

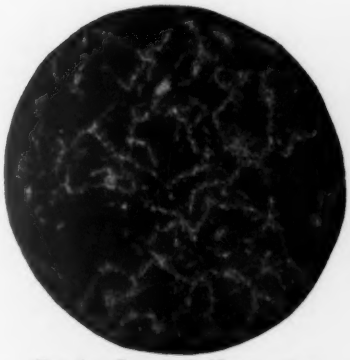


FIG. 6. — SPECIMEN NO. 2. × 70.
Held 4 hours at 800° and cooled in furnace.

FIG. 7. — SPECIMEN NO. 3. × 70.
Held 4 hours at 900° and cooled in furnace.

FIG. 8. — SPECIMEN NO. 4. × 70.
Held 4 hours at 1000° and cooled in furnace.

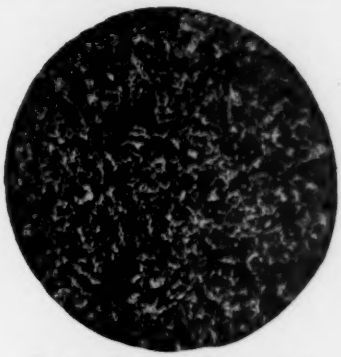


FIG. 9. — SPECIMEN NO. 7. × 70.
Cooled in air from 800°.

FIG. 10. — SPECIMEN NO. 8. × 70.
Cooled in air from 900°.

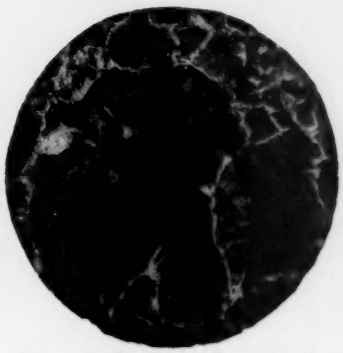


FIG. 11. — SPECIMEN NO. 9. × 70.
Cooled in air from 1000°.

is higher than in the piece heated to 900°. This is in accord with some other work in which this higher temperature seems to give increased strength. This high strength does not, however, necessarily indicate good material. The other properties must also be taken into consideration. In Series B, in which the bars were heated to definite temperatures and allowed to cool in the air from that temperature, the physical properties are in most respects more desirable than for the bars allowed to cool in the furnace. The tensile strength and elastic limit are uniformly higher, as might be expected. The more rapid cooling in this case gives much less time for crystallization to take place. The maximum elastic limit for the series is obtained at 800°, and it is to be observed that this would be indicated by the microstructure, Figure 9, which is very fine and uniform. Rather surprising is the fact that the strength of bar No. 9, heated to 1,000°, is greater than that of the original material. The microstructure of this bar was in places very coarse, consisting of large masses of pearlite, while in other places it consisted of fine granules of pearlite surrounded by ferrite, Figure 11. It may be pointed out in this connection that a coarse structure is not always associated with low strength, but the piece would, however, suffer badly from any sudden strain or shock.

In connection with the microstructure of bar No. 9, it is interesting to note the fact that a large pearlite area is invariably surrounded by an area of fine-grained pearlite. This would seem to indicate that there was a difference of surface tension between the large and small areas and that the smaller areas were diffusing into the larger, the general tendency being to reduce as far as possible the total surface energy. That this coarse structure is not due to an electrolytic effect of the etching solution, seems to be shown by the fact that different etching agents brought out the same structure, always giving the same arrangement of pearlite and ferrite. Relief-polishing likewise gave the same structure. If this formation of large crystals were an electrolytic effect, it would be difficult to conceive that nitric acid, ammonium nitrate, or alcoholic solution of hydrochloric acid would all produce similar results. Ewing and Rosenhain[1] have demonstrated that there is a difference of solubility of two crystal faces in contact with an eutectic film. Experiment-

[1] Philosophical Transactions, **195**, 279.

ing with lead, they have shown that the orientation of the lead crystal affects its solubility, and that in some cases lead is dissolved from one crystal and deposited upon another, causing the increased growth of the latter. Similar reasoning does not, however, seem to apply to the formation of large areas of pearlite, for here we

FIG. 12. — SPECIMEN NO. 13. × 70.
Cooled in furnace from 800°.

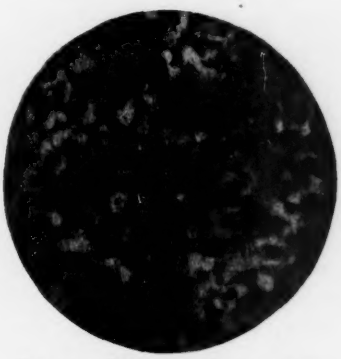


FIG. 13. — SPECIMEN NO. 14. × 70.
Cooled in furnace from 900°.

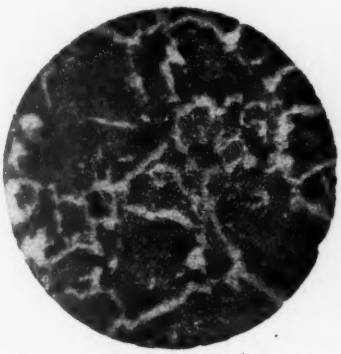


FIG. 14. — SPECIMEN NO. 15. × 70.
Cooled in furnace from 970°.

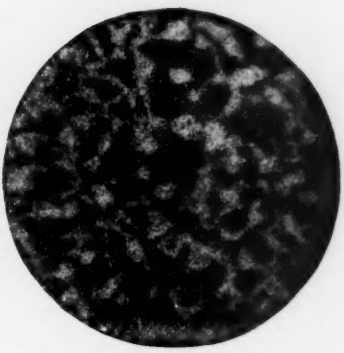


FIG. 15. — SPECIMEN NO. 16. × 70.
Cooled in furnace from 1000°.

have a complex substance which it would be difficult to conceive that it should be deposited in its characteristic form of alternate layers of iron and iron carbide. The phenomena by which large pearlite areas are produced seems to be similar to the production of large crystalline grains in any precipitate. It is a well known

fact that if we digest precipitated barium sulphate, the crystals will increase in size. This is due to the fact that the smaller crystals are more soluble than the larger ones and they are redeposited on the larger ones, the general tendency being to decrease to a minimum the surface energy. In the case of steel we seem to have a similar phenomenon. The pearlite corresponds to the barium sulphate, and the iron to the solution. At a temperature of 800° to 900°, diffusion is taking place freely, and it may easily be conceived that the smaller areas are diffusing into the larger ones. On heating to the higher temperatures, these areas are developed, and also have their influence upon the coarseness of the fracture.

In Series C, those bars heated to a definite temperature and allowed to cool from that temperature in the furnace, do not show a very marked difference from Series A. The tensile strength is on the average slightly higher, the elastic limit uniformly lower, the contraction of area lower, and the elongation shows on an average about the same values. Compared with Series B, Series C shows uniformly lower tensile strength and elastic limit.

The microstructure of this series is similar to Series A and B in the specimens heated below 800°. The complete blurring of the microstructure seems to have taken place between 800° and 900°. Specimen 14 heated to 900° resembles Specimen 4 heated to 1,000°, and not Specimens 3 and 8 heated to 900°. Complete diffusion evidently took place at about 850°, because the specimen heated to 800° shows some of the blurred effect, and at 900° it seems to have passed partly through this stage. Heated to 970°, Specimen 15 shows large masses of lamellar pearlite surrounded by wide channels of ferrite. Specimen 16 shows dense segregated masses of pearlite. The tensile strength of this piece is abnormally low, and should not show such a variation from Specimen 4 heated to the same temperature for four hours before cooling in the furnace. The rate of heating and cooling has a strong influence on the properties of this material, and it may have been that this specimen was not heated in the same manner as the others, although considerable care was taken to have all conditions as uniform as possible.

The most notable changes occur in this steel in the neighborhood of 900° and not at Ac_1, as would be expected. Whether this is due to the fact that some element is exerting a retarding influence, or whether some unknown influence is acting, remains for

further investigation. Judging from the microstructure and the physical properties of Specimen No. 7, the most satisfactory heat treatment would be to heat to a temperature of 800° and to cool in the air. Of course it must be borne in mind that all of the results obtained are only relative, because the original material received considerable work in the process of manufacture, and this exerted an enormous influence on the properties. The heat treatment as outlined, therefore, refers more particularly to the changes produced in a piece of axle steel which is ready for service.

ON THE PRACTICAL VALUE OF PRESUMPTIVE TESTS FOR BACILLUS COLI IN WATER.[1]

By GEORGE C. WHIPPLE.

Introduction.

The status of the test for *Bacillus coli* in the sanitary examination of drinking water at the present time is one of great uncertainty, and yet there is no subject of more practical importance. The uncertainty is caused in part by the fact that there is no one method generally accepted by which the presence of this organism in water is determined. Each bacteriologist has his own way of isolating it and studying it in pure culture, and the results obtained by these different methods fail to agree. The bacillus itself, in spite of an immense amount of study, is one which cannot be always recognized by the usual methods employed. Its different races and strains so insensibly merge into allied species, and there are such gradations between *Bacillus coli* and *Bacillus typhi* on the one hand and between *Bacillus coli* and several species of common water bacteria on the other hand, that with our present tests it is almost impossible to say what shall or what shall not be called *Bacillus coli*. The type form of *Bacillus coli* is one which can be defined within reasonably narrow limits, but when the organism has been away from its natural habitat for varying periods of time, and has existed under abnormal conditions, its ability to react normally to the usual tests appears to be greatly impaired. Its power to reduce nitrates may be lost, or on the other hand, it may be much increased; its power to produce indol may be lost, or on the other hand, it may be increased; its power to coagulate milk, even, is sometimes reduced, although seldom entirely lost; its power to ferment carbohydrates may be altered so that the amount of gas obtained in a fermentation tube, as well as its ratio of H to CO_2, is quite abnormal. But in spite of all these facts, the bacillus

[1] Paper presented at the meeting of the Laboratory Section of the American Public Health Association held at New Orleans on December 8, 1902.

tested may have been originally a true *Bacillus coli*. It happens, therefore, that a sample of water may contain this bacillus without its being recognized, and it happens also, and perhaps more frequently, that other organisms closely related to this species but different from it, may be recorded as *Bacillus coli*. And this has led to a wide divergence of ideas concerning the distribution of the species in nature, and to the practical significance of positive tests for it in water. So great has been the discord in regard to the results obtained by the usual tests that it has been questioned by some sanitarians as to whether the test as ordinarily made has any practical significance at all. It is my purpose in this article to show that in spite of all these varying results, the test for *Bacillus coli* is one of great usefulness.

In order to determine definitely whether *Bacillus coli* is present or is not present in a sample of water, it is necessary to isolate the germ and study it in pure culture. This involves a long series of operations, and is a time-consuming process. It is seldom that a reliable result can be obtained inside of one week, and preferably the test should extend over a period of ten days, in order to allow for preliminary cultivation.

The following tests may be considered necessary to establish beyond a doubt the identity of the organism:

1. Typical morphological characteristics and motility, as determined from a young broth culture.

2. The non-liquefaction of gelatin as determined by a stab-culture incubated for at least one week, and preferably for a longer period.

3. The fermentation of dextrose broth in a Smith tube. The amount of the gas should be normally between 30% and 70% of the volume of the closed arm, and the percentage which the carbonic acid is of the total amount of gas should be approximately one-third. The closed arm should be turbid and the open bulb should show a strongly acid reaction. It should be noted, however, that both the amount of gas and the percentage of carbonic acid are subject to variation, even with freshly isolated cultures of *Bacillus coli*, so that these quantities must not be given a too strict interpretation.

4. The production of indol in Dunham's Solution, when tested by the "Ring Method" after an incubation of 48 hours at 37° C.

5. The characteristic coagulation of milk, with the production of acid, in 48 hours at 37° C.

6. The reduction of nitrates in 48 hours at 37° C.

7. The non-formation of spores, as determined by the inability of a culture to develop after heating for ten minutes at 80° C.

The most constant of the above tests are the characteristic morphology, non-liquefaction of gelatin, fermentation of carbo-hydrates, and the coagulation of milk. The tests for indol production and nitrate reduction are somewhat more erratic than the others. Before the above tests can be made, it is first necessary to isolate the organism from the water in pure culture. This has been accomplished in a variety of ways. For example: Gelatin plates, agar plates, lactose-litmus-agar plates, phenol-agar plates, or plates of agar which have been otherwise treated in order to inhibit the growth of ordinary water bacteria, are fished, and the cultures put through the regular tests. Or, the sample is added to dextrose broth in a Smith tube, and, if the characteristic fermentation is obtained, is thereafter plated out on agar or some modification of it, as described above, and these plates ultimately fished. Or, the sample of water in quantities which may vary from .01 c.c. to 1 litre, is enriched by the addition of carbolized dextrose broth, or some similar medium, and given a preliminary incubation, after which transfers are made to lactose-litmus plates or to the fermentation tube. In fact, the methods used for isolating *Bacillus coli* in pure culture are varied according to the idiosyncrasies of the operator and the character of the water to be tested. It is not my purpose to describe here these various methods, many of which are of considerable value, and no one of which can be considered as superior to the others for all cases. I wish simply to emphasize the fact that the operation is a tedious and laborious one. In the practical supervision of water supplies it often happens that there is no time for carrying out all of the tests required to obtain an absolutely conclusive result, and that an approximate test which may be quickly made may have greater practical value than the ultimate test. For example: If it only takes 4 days for the water of a reservoir to reach the service taps in a city, and if it requires a week to make a test, the result of a conclusive test could not be learned until several days after the water had been used; while if a presumptive test could be obtained in 48 hours, it might materially affect the management of the water

supply. Hence it is important that the subject of presumptive tests for the presence of *Bacillus coli* should not be overlooked. I have studied this subject with considerable care, and have made practical tests of nearly all methods which have been suggested, including the most recent ones, namely, the neutral red test and the sodium-taurocholate, or bile salt test, as suggested by McConkey; but after all my studies I have found nothing of more practical value than the simple fermentation-tube-test, as first outlined by Smith; and his original test has been modified only by operating upon different volumes of water for each sample. The method of procedure which is used at Mount Prospect Laboratory is as follows:—

Method of Making Presumptive Tests.

Smith tubes of the ordinary form are used, the closed arm being 5 inches long and about $\frac{1}{2}$ inch inside diameter. The following is the formula of the broth used:

Liebig's Beef Extract . . .	10 grams.
Pepton	10 "
Dextrose	10 "
Water	1,000 "

The reaction is made 0%, and the correctness of this reaction is a matter of no little importance.

The medium is made up in batches of 5 litres and kept in flasks until needed to be used in the Smith tubes. Sterilization is made in the autoclave. When quantities of water of .001, .01, .1, 1.0 or 10 c.c. are to be tested, these quantities are added directly to the broth in the Smith tubes, the fractional portions being obtained, of course, by dilution. When larger quantities, such as 100, 500 or 1,000 c.c. are to be tested, they are first enriched by the addition of carbolic dextrose broth of such a strength that after addition to the water the mixture shall contain 1% of dextrose and 0.1% of phenol. After preliminary incubation for a period not exceeding 12 hours, 1 c.c. of the culture is added to a fermentation tube. If the enriched samples are allowed to stand too long, other organisms, such as streptococci, for example, may outgrow *Bacillus coli* so that a negative result may be obtained. The fermentation tubes are incubated at 37° for 48 hours, and are then tested for per cent. of gas, percentage of carbonic acid, reaction of the open bulb, and tur-

bidity of closed arm. The typical reaction which is considered as a positive test for the presence of *Bacillus coli* in the sample tested is as follows: Total gas, between 25 and 70 per cent. of the closed arm; per cent. which the carbonic acid is of the total gas, between 25 and 40; the closed arm, turbid; the open arm, strongly acid to litmus and usually not accompanied by the formation of a scum. If the amount of gas formed is between 10 and 25 per cent., or if it is more than 70 per cent., the test is considered as atypical; or, if the amount of gas is between 25 and 70 per cent., and the per cent. of carbonic acid greater than 40, the test is considered as atypical; or, with the proper gas reactions, but with the open arm alkaline instead of acid, the test is considered as atypical. If no gas forms, or if it is less than 10 per cent., the test is called negative.

It is recognized that this test is not absolute. It has frequently happened that pure cultures isolated from Smith tubes which gave a positive test have failed to yield true cultures of *Bacillus coli* when carried through all the tests by sub-culture; and on the other hand, it has occasionally happened, though rarely, that true cultures of *Bacillus coli* have been obtained from Smith tubes which yield atypical results. But speaking broadly, the typical reactions offer satisfactory presumptive evidence of the presence of this species, or species very closely allied to it.

In a subsequent paper, I hope to give the data to support this assertion, but at this time will offer as corroborative testimony the statement of Mr. Irons, who in his paper on "Some Observations on Methods for the Detection of *Bacillus coli communis* in Water," states: "When the dextrose tube yields approximately 33 per cent. of CO_2, *Bacillus coli communis* is almost invariably present."

Eccentricities of the Test.

When varying quantities of a sample of water are tested in series, it sometimes happens that a positive test is obtained with a small amount, while with larger amounts the results are negative. This anomalous result is due in part to chance, but chiefly to the rapid development, during the preliminary incubation, of bacteria which are not *Bacillus coli*, and which tend to obscure the reaction. It has been observed by Winslow, Gage, and others, that certain streptococci are most commonly the cause of this interference, and

this has been also my own experience. Furthermore, in the waters which have come to me for examination streptococci have been less numerous than *Bacillus coli.* Consequently, when small amounts of water have been tested they have been less likely to cause interference than when large amounts have been examined.

In order to show the frequency with which these interferences occur, the following figures are presented. 140 samples of water were tested, in quantities of 0.1, 1.0, and 10.0 c.c., with the results shown in Table I.:

TABLE I.

SHOWING THE RESULTS OF PRESUMPTIVE TESTS FOR BACILLUS COLI WITH DIFFERENT QUANTITIES OF WATER.

	PER CENT. OF SAMPLES.		
NUMBER OF C.C. OF WATER TESTED.	0.1	1.0	10.0
Positive Tests.	4.0	9.8	24.4
Atypical Tests.	1.3	18.0	30.4
Negative Tests.	94.7	72.2	45.2
Negative Tests in cases where positive tests were obtained with smaller quantities of water.	0.0	2.9	4.3
Negative Tests in cases where atypical tests were obtained with smaller quantities of water.	0.0	0.0	2.8
Positive Tests (Corrected).	4.0	12.7	28.7
Atypical Tests (Corrected).	1.3	18.0	33.2
Negative Tests (Corrected).	94.7	69.3	38.1

It will be seen from this that 2.9% of the samples gave positive tests with 0.1 c.c., but not with 1 c.c., while 4.3% of the samples gave positive tests with 0.1 or 1 c.c., and negative tests with 10 c.c. Again, 169 samples which were tested in quantities of 1, 10, 100 and 500 c.c. gave results shown in Table II.

TABLE II.

SHOWING THE RESULTS OF PRESUMPTIVE TESTS FOR BACILLUS COLI IN DIFFERENT QUANTITIES OF WATER.

	Per Cent. of Samples.			
Number of Cubic Centimeters of Water Tested.	1	10	100	500
Positive Tests.	17.2	26.6	37.9	40.8
Atypical Tests.	25.4	32.6	37.3	37.3
Negative Tests.	57.4	40.8	24.8	21.9
Negative Tests in cases where positive tests were obtained with smaller quantities of water.	0.0	3.0	5.3	4.8
Negative Tests in cases where atypical tests were obtained with smaller quantities of water.	0.0	5.3	4.7	7.7
Positive Tests (Corrected).	17.2	29.6	43.2	45.6
Atypical Tests (Corrected).	25.4	37.9	42.0	45.0
Negative Tests (Corrected).	57.4	32.5	14.8	9.4

It was found that 0.1% phenol broth possessed but little advantage over uncarbolized broth for preliminary cultivation, and that it made but little difference whether the temperature of the incubator was kept at 37.5° C. or at 42° C., but that it was a decided advantage to use a short period of incubation rather than one which extended over eighteen hours.

The interference of streptococci and other organisms with the presumptive test as conducted in the manner described above is troublesome and difficult to avoid, but, in my experience, it has been found to be serious only in about five per cent. of the samples tested. Whenever a positive test for *Bacillus coli* is obtained with a small quantity of water, it is safer to assume that larger quantities will also give a positive test, than to assume that the positive test in the small quantity was accidental.

Practical Value of the Presumptive Test.

As an illustration of the value of this test, I beg to call attention to the diagram shown in Figure 1. This gives the results of chemical and bacteriological examinations of certain surface water

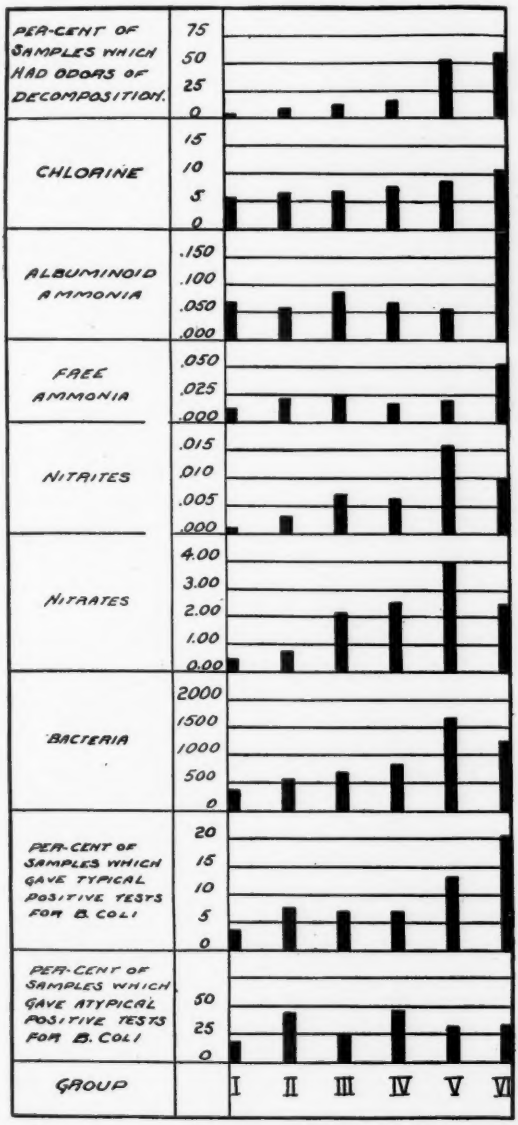


FIG. 1.— DIAGRAM SHOWING THE RELATION OF TYPICAL AND ATYPICAL PRESUMPTIVE TESTS FOR B. COLI TO THE SANITARY ANALYSES OF VARIOUS SURFACE WATERS, ARRANGED IN GROUPS ACCORDING TO THEIR RELATIVE POLLUTION.

supplies, classified in six groups according to their relative pollution, as determined by inspection of the watersheds. Each group represents several different streams, and the results are based on weekly observations extending over a period of four years. As an indication of the varying degrees of contamination to which the waters are submitted, it may be stated that Group I includes only waters which are collected from almost uninhabited watersheds, while Group VI includes waters too much polluted to be safely used for domestic purposes, and the intermediate groups occupy relative positions between these two extremes. It will be observed from the diagram that the percentage of samples which had odors of decomposition, the average amounts of chlorine, free ammonia, nitrites, nitrates and the number of bacteria per c.c., show a general increase from left to right. The nitrogens are somewhat influenced by the presence of coloring matter and microscopic organisms, so that the sequence is not so regular as otherwise might be the case. It will be observed that the percentage of samples which gave typical positive tests for *Bacillus coli* with 1 c.c. show an increase from the unpolluted waters to the polluted waters, which corresponds well with the increase of bacteria, chlorine, and odors of decomposition, and with the known facts as to the pollution of the streams in question. None of the water supplies is polluted by the discharge of sewage which directly enters the stream; in all cases the pollution may be considered as indirect. Still more striking is the value of the presumptive test when applied to different amounts of water. This is illustrated in Table III.

TABLE III.

SHOWING THE PER CENT. OF SAMPLES WHICH GAVE POSITIVE TESTS FOR BACILLUS COLI WHEN DIFFERENT AMOUNTS OF WATER WERE EXAMINED. BASED ON WEEKLY OBSERVATIONS COVERING A PERIOD OF TWO MONTHS.

GROUP.	0.1 C.C.	1.0 C.C.	10 C.C.	100 C.C.	500 C.C.
I	0.0	3.5	20.8	50.0	50.0
II	5.0	7.3	15.0	60.0	60.0
III	0.0	7.0	50.0	50.0	60.0
IV	4.0	6.8	41.7	67.0	75.0
V	5.0	13.0	75.0	100.0	100.0
VI	5.0	20.2	75.0	80.0	100.0

From this it is seen that positive tests for *Bacillus coli* are obtained from watersheds that are practically unpolluted. Indeed, it has been my experience that practically all surface waters will give positive presumptive tests for *Bacillus coli* if sufficiently large quantities of water are tested. As the amount of pollution increases, the quantity of water necessary to give the positive reaction diminishes, until in very polluted waters the amount required may be but a fraction of a cubic centimeter. This has been shown by Dr. Jordan in his studies of the Chicago Drainage Canal, and by the Liverpool school of bacteriologists in England in their studies of sewage.

Just where to draw the line between "good" and "bad" waters cannot be said until the application of this method has been more widely extended, but as a provisional schedule of interpretation, the following is suggested, though with some hesitation and with the expectation that it will be modified by subsequent studies.

Sanitary Quality.	Presumptive Test for Bacillus Coli.				
	0.01 c.c.	0.1 c.c.	1.0 c.c.	10.0 c.c.	100 c. c.
Safe.	0	0	0	0	+
Reasonably safe.	0	0	0	+	+
Questionable.	0	0	+	+	+
Probably unsafe.	0	+	+	+	+
Unsafe.	+	+	+	+	+

It is to be remembered that this schedule refers to the presumptive test as made above, and not to the isolation of the bacillus by the more elaborate methods of sub-cultures. Furthermore, this test is not to be considered alone and as all-sufficient; it is to be treated as but one part of a sanitary analysis which includes a chemical as well as a biological examination, and the complete analysis must be used in making a final judgment upon the water. Comparisons of the results of positive tests with the rainfall on the watershed of the Brooklyn Water Supply show that a majority of the positive tests have occurred immediately after heavy rains, indicating that the pollution was washed into the streams from the surface—as is known to be the case. Moreover, studies of the seasonal distribution show that there is a tendency to increased numbers of posi-

tive tests in the spring and fall, when farmers are manuring their fields. Whether or not, therefore, this test indicates absolutely the presence of *Bacillus coli* in the water, it is certainly an indication of an inferior sanitary condition.

Positive Presumptive Tests for Bacillus Coli in Ground Water.

When a typical positive presumptive test is obtained for the presence of *Bacillus coli* in ground water, it is an almost infallible indication of the presence of contamination with surface water. The following may be taken as an illustration:

A certain driven well station was located in swampy land, along the shores of a stream, and the tops of the wells were so placed that they were occasionally flooded at times of high water. The water in the stream was objectionable from the sanitary standpoint. The wells themselves were more than 100 feet deep; they penetrated a clay bed and yielded what may be termed artesian water. Tests for the presence of *Bacillus coli* had invariably given negative results, as might be naturally expected. Suddenly, however, the tests became positive, and so continued for several days. On investigation it was found that some of the wells had been taken up to be cleaned, and that the workmen in resinking them had used the water of the brook for washing them down. This allowed some of the brook water to enter the system. It was also found that at the same time the water in the brook had been high, and because of the lack of packing in certain joints at the top of the wells, the brook water leaked into the suction main. The remedy was obvious, and was immediately applied, after which the tests for *Bacillus coli* once more became negative. During all this time the chemical analysis of the water was not sufficiently abnormal to attract attention. On another occasion, a water supply taken from a small pond fed by springs, and which was practically a large open well, began to give positive tests for *Bacillus coli*, and on examination it was found that a gate which kept out the water of a brook which had been formerly connected with the pond, was open at the bottom, although it was supposed to have been shut, thus admitting a contaminated surface water to the supply.

The methods which are in vogue in England for determining the presence of *Bacillus coli* in water cannot be considered as strict as those ordinarily employed in this country, and their results can be

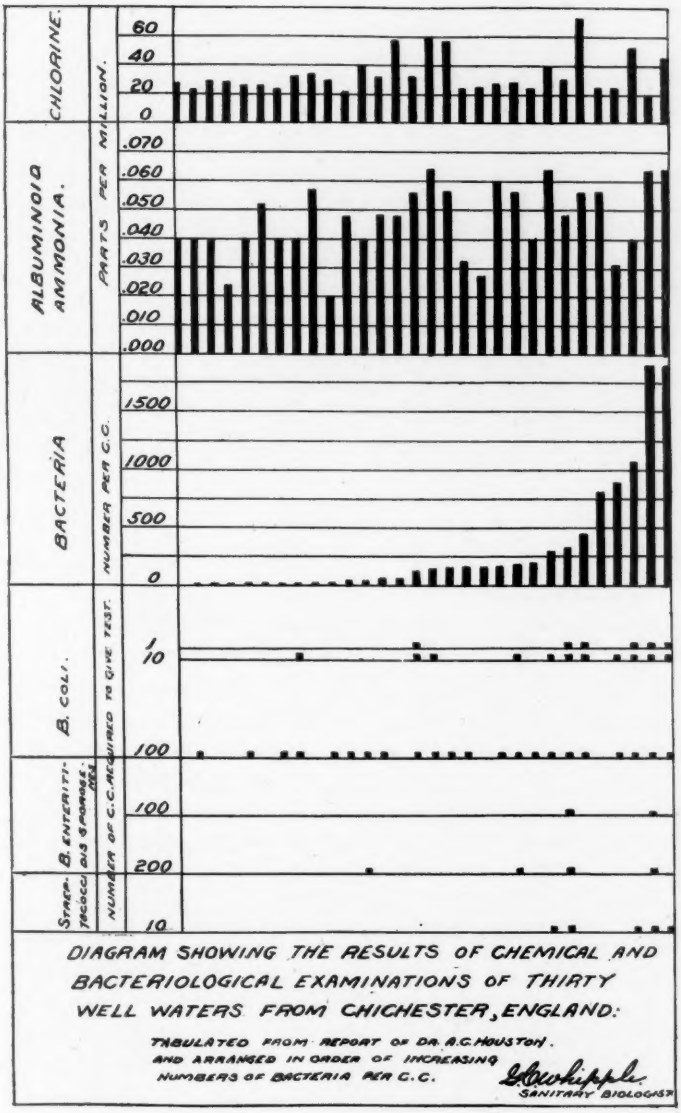

CHLORINE.
PARTS PER MILLION.
60
40
20
0
ALBUMINOID AMMONIA.
.070
.060
.050
.040
.030
.020
.010
.000
BACTERIA
NUMBER PER C.C.
1500
1000
500
0
B. COLI.
NUMBER OF C.C. REQUIRED TO GIVE TEST.
1/10
100
B. ENTERITIDIS SPORGENES (KLEBS).
100
200
STAPH.
10
DIAGRAM SHOWING THE RESULTS OF CHEMICAL AND BACTERIOLOGICAL EXAMINATIONS OF THIRTY WELL WATERS FROM CHICHESTER, ENGLAND.
TABULATED FROM REPORT OF DR. A.C. HOUSTON.
AND ARRANGED IN ORDER OF INCREASING NUMBERS OF BACTERIA PER C.C.
G.C. Whipple
SANITARY BIOLOGIST

FIG. 2.

better compared with those of our presumptive tests than with the ultimate tests as made according to American methods. In the 30th Annual Report of the Local Government Board of Great Britain, there is an interesting report by Dr. A. C. Houston on "The Chemical and Bacteriological Examination of Chichester Well Waters." He gives a series of figures showing the results of chemical and bacteriological tests of a large number of open wells. These results are shown graphically in Figure 2, arranged in order of increasing number of bacteria. It will be seen from this table that there was little correspondence between the total number of bacteria and either the chlorine or the albuminoid ammonia, while the results obtained by the bacteriological examination seemed to hold together very satisfactorily. It will be noticed that there was a gradual increase in the number of *Bacillus coli* in the water from the left to the right of the diagram, thus corresponding with the increase in the total number of bacteria. The test for *Bacillus enteritidis sporogenes* and streptococci gave corresponding results.

Presumptive Test for Bacillus Coli as an Index of the Efficiency of Filtration.

The practical value of the presumptive test is also shown when used to determine the efficiency of filters. This has been well illustrated by the experiments made at Lawrence, Mass., by the State Board of Health, the results of which have been already presented to this Section. The following example, taken from the records of a test of a mechanical filter, is also of interest in this connection:

TABLE IV.

Showing the Results of Presumptive Tests for Bacillus Coli in Different Amounts of Water before and after Filtration through a Mechanical Filter.

Period.	Water.	Number of Samples.	Per Cent. of Positive Tests.			
			1 c.c.	10 c.c.	100 c.c.	500 c.c.
Filter working well.	Raw Water.	15	6.7	40.0	40.0	40.0
	Filtered Water.	15	0.0	0.0	7.0	6.7
Filter working badly.	Raw Water.	16	18.7	43.7	68.7	56.2
	Filtered Water.	16	31.2	50.0	37.5	56.2

For fifteen days, during which the filter was doing good work, as shown by the chemical analysis and by its removal of bacteria, 6.7% of the samples of raw water gave positive tests when tested with 1 c.c., while the per cent. of samples of filtered water which gave positive tests was 0. When tested with quantities of 500 c.c., 40% of the samples of raw water gave positive tests, and 6.7% of the samples of filtered water. During a period of sixteen days, when the filter was doing poor work, as shown by the chemical analysis and general appearance of the effluent, 18.7% of the samples of raw water gave positive tests in 1 c.c., while 31.2% of the samples of filtered water gave positive tests. When tested in quantities of 500 c.c., 56.2% of the samples of raw water gave positive tests, and 56.2% of the samples of filtered water gave positive tests. Thus, during the first period the filter was yielding a water which contained very few *Bacillus coli*, as determined by the presumptive tests, while during the second period the filtered water was no better than the raw water.

Summary.

The foregoing may be summarized as follows:

1. The methods necessary for the certain identification of *Bacillus coli* in water involve technique so complicated and so time-consuming that they are not practical as working tests in connection with the supervision of water supplies.

2. The fermentation of dextrose broth, as first suggested by Dr. Theobald Smith, furnishes the most rapid and most practical test for the presence of *Bacillus coli* in water.

3. The extension of this test to cover different quantities of water in the same samples, thus making the test quantitative (within limits) as well as qualitative, greatly enhances its value.

4. *Bacillus coli*, if not itself widely distributed in nature, resembles certain common bacteria in all points covered by the usual tests, to such an extent as to throw doubt upon the use of this organism as a conclusive test for fecal contamination.

5. But whether or not *Bacillus coli* is solely an intestinal germ, the presumptive test described above is a useful test to determine the sanitary quality of water, and is one which gives results that agree well with chemical and biological analysis.

Mt. Prospect Laboratory,
Brooklyn, N. Y.

A COMPARISON OF VARIOUS TESTS APPLIED TO PAINTS USED FOR THE PROTECTION OF IRON.

By AUGUSTUS H. GILL and CHARLES C. JOHNSON.

The necessary qualifications of a paint to prevent rust are: (1) That it shall be impervious to and unaffected by moisture or other atmospheric influences. (2) That it shall form a surface sufficiently hard to be durable and yet sufficiently elastic to conform to the expansion and contraction of the metal. (3) That it shall adhere firmly to the surface to which it is applied. (4) That it shall not corrode the metal to which it is applied.

Among the various practical tests for ascertaining the value of paints as a protection against rust are the following: (1) Loesner's steam test. (2) "The water and moisture test." (3) Immersion in water. (4) Test of the electrical insulation. (5) Heat test.

The object of this investigation was to make a comparative test of these different methods and to decide, if possible, whether the value of a paint when in actual use can be ascertained by any such laboratory experiments. This permitted, at the same time, a comparison of the various paints themselves.

The tests enumerated were carried out in the following manner:

Loesner's steam test.[1] — Strips of sheet iron are carefully cleaned upon an emery wheel and coated with two layers of paint, each layer being allowed to dry four days, care being taken in every case that the first coat was thoroughly dried before the second was applied. The strips are placed over the apertures of a constant-level water bath at the height of about 5 cm. above the water and supported upon strips of wood at each end to prevent abrasion. After 15 hours' exposure to the ascending steam, the paint is dried at 100°C., softened with aniline, and removed with a soft brush. The strips are dried with alcohol and their surfaces examined for rust. A paint

[1] Chem. Rev. Fett u. Harz Ind. **4**, 329.

is considered to be satisfactory which after 15 hours' exposure to the steam permits no rusting of the metal beneath it.

"*The water and moisture test*" is performed by painting the inner surface of a shallow iron dish, which has previously been cleaned by the sand blast, and exposing the paint to the action of slowly evaporating water. The water is allowed to evaporate to dryness at the ordinary temperature of the room, the dish refilled — usually once a week — and the evaporation repeated until the interior of the dish shows more or less rust. The condition of the surface is carefully examined before each refilling. The dishes used were 10 cm. in diameter and 2 cm. deep.

The next test, that of *immersion in water*, consists simply in exposing the painted iron strips to the continuous action of water. In this work the strips were placed in beakers 5 inches deep, so that the water level stood about $\frac{1}{2}$ an inch below the edge of the painted surface, the water being kept at approximately constant level.

The test of *electrical insulation* was made by preparing and painting the strips as in the other tests. A dam was made on each strip and filled with mercury, which served as an electrode and insured good contact between the pole and the paint coating. The dams were made by fastening rubber washers to the strips by means of wax; the remainder of the operation consisted in clamping one pole of a testing transformer to the bare metal and dipping the other pole into the mercury. Direct current is preferably used, although in these experiments an alternating current was employed. The voltage was increased until the insulation failed. This test indicates the relative continuity of the coatings, since a porous film will allow the current to pass through it readily.

The heat test was made by subjecting the paint to a temperature of 400° F. for two hours in an oven. That which offers the greatest resistance to heat is, so far as this test is concerned, the best paint. The heat promotes oxidation and produces in a few hours an effect similar to that which would be obtained very slowly at ordinary temperatures.

TABLE I. SHOWING THE BEHAVIOR OF VARIOUS PAINTS WHEN SUBJECTED TO LOESNER'S STEAM TEST.

PAINT.	APPEARANCE OF COATING OR METAL.
Dixon's graphite (2 tests).	Coating appeared rubber-like and could be scraped off easily; 8-10 medium-sized blisters formed.
Durable metal coating (2 tests).	Coating adhered well, but was somewhat porous.
Prince's mineral brown (2 tests).	Coating was covered with very small blisters which could be scraped off easily.
Bessemer (iron oxide) (2 tests).	Many blisters formed.
Raw linseed oil (applied hot).	Strip rusty.
Boiled linseed oil.	Strip corroded for half its surface.
Black enamel (2 tests). (tar)	Very large blisters formed; coating could be brushed off very easily.
Red lead 78%, raw oil 22%.	Somewhat porous; condition good.
Red lead 78%, raw oil 22%.	Condition good.
Red lead and lucol * (2 tests).	Condition good.
Red lead 30%, raw oil 10%, white lead 60% (2 tests).	Very small blisters formed; condition good.
First coat red lead, second coat white lead (2 tests).	Small blisters formed; condition good.
Red lead 56%, white lead 28%, raw oil 16% (2 tests).	Coating full of pores and small blisters.
Barytes 86%, boiled oil 14% (2 tests).	Coating full of pores and small blisters and could be easily scraped off.
Red oxide of iron and raw oil (2 tests).	Coating very tender and could be easily scraped off.
Zinc oxide and raw oil (2 tests).	Coating tough and in good condition, appeared rubber-like and shrivelled.
Zinc white 51%, barytes 38%, raw oil 11% (2 tests).	Coating porous.
White lead 60%, zinc oxide 30%, raw oil 10% (2 tests).	Condition good.
White lead and raw oil (2 tests).	Small blisters formed in coating.
White lead and lucol (2 tests).	Small blisters formed in coating.
White lead 57%, barytes 43%, raw oil (2 tests).	Coating blistered.
First coat red lead, second coat graphite.	Coating somewhat porous and covered with small blisters.
First coat red lead, second coat red oxide.	Covered with very small blisters.
As the preceding, using lucol (2 tests).	Covered with very small blisters.
Pure rosin varnish (2 tests).	Coating nearly all removed.
Half rosin and half kauri varnish (2 tests).	Coating adhered very well, but blistered considerably.
Pure kauri varnish.	Coating covered with small blisters.
Suspected varnish.	Very small blisters formed.

* Lucol is said to be a mixture of about equal parts of a light mineral oil with fish oil which has been treated with sulphur chloride; this is used as a substitute for linseed oil.

TABLE II. SHOWING THE BEHAVIOR OF VARIOUS PAINTS UNDER THE "WATER AND MOISTURE TEST."

PAINT.	TIME OF EXPOSURE IN DAYS.	APPEARANCE OF COATING OR METAL.
Dixon's graphite.	7	A few very small blisters.
	36	Covered with very small blisters.
Durable metal coating.	28	Condition good.
	36	General condition good; a few rough patches formed.
	53	A few small rust spots.
	61	Covered with small blisters.
Prince's mineral brown.	12	Covered with small blisters.
	57	Covered with small blisters.
Bessemer.	17	Condition good.
	26	Small blisters formed.
	40	Covered with blisters.
	49	Corroded.
Raw linseed oil.	11	Slightly corroded.
	32	Corroded.
Boiled linseed oil.	9	Like rubber.
	17	Corroded.
	28	Rusty.
Red lead, raw oil.	61	Condition good.
Red lead, lucol.	46	Condition good.
Red lead 30%, white lead 60%, raw oil 10%.	36	Condition good.
First coat red lead, second coat white lead.	36	Condition good.
Barytes, boiled oil.	7	Covered with small blisters.
	28	Corroded.
Red oxide of iron, raw oil.	22	Condition good.
	33	Corroded at edge.
	46	Small blisters.
	60	Corroded on sides of dish.
Red oxide of iron, boiled oil.	11	Covered with small blisters.
	36	Partly corroded.
Zinc white, raw oil.	12	A few rust spots.
	34–49	Rust spots increased in size.
White lead, zinc oxide, raw oil.	12	Several spots of rust.
	23–49	Rust spots increased in number.
White lead, lucol.	10	Condition good.
	18	Specks of rust.
White lead, raw oil.	16	Condition good.
	26	Small specks of rust.
Rosin varnish.	11	Several spots of rust.
	34	Most of coating white.
	45	Covered with blisters.
Rosin and kauri varnish.	9	Part of coating white.
	20	Somewhat blistered.
	41	Covered with small blisters.
	53	Partly corroded.
Pure kauri varnish.	11	A few spots of rust.
	34	Partly corroded.
	45	Corroded and covered with small blisters.
Suspected varnish.	9	Covered with specks of rust.
	30	Covered with small blisters.
	41	Corroded.

TABLE III. SHOWING THE BEHAVIOR OF VARIOUS PAINTS UNDER THE "IMMERSION IN WATER TEST."

PAINT.	TIME OF IMMERSION IN DAYS.	APPEARANCE OF COATING OR METAL
Dixon's graphite.	40	Covered with small blisters.
Durable metal coating.	40	Covered with medium-sized blisters.
Prince's mineral brown.	40	Quite tough; covered with small blisters.
Bessemer.	40	Covered with large blisters.
Raw linseed oil.	40	Corroded; small blisters.
Boiled oil.	40	Corroded.
Red lead, raw oil.	40	Condition good.
Red lead, lucol.	25	Coating tender.
Red lead 30%, white lead 60%, raw oil 10%.	25	Condition good; coating tough.
First coat red lead, second coat white lead.	25	Condition good; coating tender.
Barytes, boiled oil.	40	Covered with small blisters; coating quite tough.
Red oxide of iron, raw oil.	40	Covered with small blisters; coating tender.
Red oxide of iron, boiled oil.	25	Covered with small blisters.
Zinc white, raw oil.	40	Covered with rust spots; coating quite tender.
White lead 60%, zinc white 30%, raw oil 10%.	40	Several rust spots; coating quite tender.
White lead, lucol.	25	A few small rust spots; coating quite tough.
White lead, raw oil.	40	A few small blisters; coating tender.
White lead 57%, barytes 33%, raw oil 10%.	25	Condition fair; coating quite tender.
Rosin varnish.	15	Covered with large blisters.
Rosin and kauri varnish.	15	Covered with large blisters.
Suspected varnish.	15	Corroded at surface of water.
Kauri varnish.	15	Covered with small blisters.

TABLE IV. TEST OF ELECTRICAL INSULATION.

PAINT.	VOLTAGE AT WHICH COATING FAILED.	AVERAGE.
Dixon's graphite.	<300	<300
Durable metal coating.	440, 650, 550	547
Prince's mineral brown.	700, 550, 650	633
Bessemer.	<300	<300
Black enamel.	<300	<300
Barytes, boiled oil.	670, 450	560
Red lead, raw oil.	1700, 1680, 1740	1707
Red lead, lucol.	300, 523, 450, 480	438
First coat red lead, second coat white lead.	790, 1060, 700	850
Red lead 56%, white lead 28%, raw oil 16%.	600, 480, 1100	727
Red lead 30%, white lead 60%, raw oil 10%.	700, 720, 560	660
Red oxide, raw oil.	<300	<300
Boiled oil.	<300	<300
First coat red lead, second coat red oxide.	930, 950, 870	917
First coat red lead, second coat graphite.	500, 620, 600	573
Zinc white, raw oil.	660, 610, 620	630
White lead 60%, zinc white 30%, raw oil 10%.	750, 580, 480	603
Zinc white 51%, barytes 38%, raw oil 11%.	860, 550, 680	697
White lead, raw oil.	650, 340, 540	510
White lead, lucol.	810, 810, 860	827
White lead 54%, barytes 40%, raw oil 6%.	630, 650, 970	750
Red lead, raw oil.	760, 640, 540	647
Prince's mineral brown.	710, 820, 700	743
Lucol oil.	<300	<300
Suspected varnish.	620, 900, [2600], 600	707
Rosin varnish.	580, 520, 520	540
Rosin and kauri varnish.	410, 380	395
Kauri varnish.	420, 370	395

TABLE V. HEAT TEST. TEMPERATURE 400°F. TIME 2 HOURS.

PAINT.	APPEARANCE.
Dixon's graphite.	Condition good.
Durable metal coating.	Small cracks on surface; coating adhered well.
Prince's mineral brown.	Condition good.
Bessemer.	Condition good.
Barytes 86%, boiled oil 14%.	Came off in scales.
Black enamel.	Brittle; peeled off.
Red lead 78%, raw oil 22%.	Brittle; peeled off.
Red lead 30%, white lead 60%, raw oil 10%.	Brittle; peeled off.
Red lead 78%, lucol 22%.	Brittle; peeled off.
First coat red lead, second coat white lead.	Brittle; peeled off.
Red lead 56%, white lead 28%, raw oil 16%.	Brittle; peeled off.
Red oxide, raw oil.	Condition good.
Red oxide, boiled oil.	Condition good.
Zinc white, raw oil.	Peeled off.
Zinc white 51%, barytes 38%, raw oil 11%.	Very good.
White lead 60%, zinc white 30%, raw oil 10%.	Brittle.
White lead, lucol.	Peeled off.
White lead, raw oil.	Blistered: peeled off easily.
White lead 54%, barytes 40%, raw oil 6%.	Peeled off.
Rosin varnish.	Peeled off.
Rosin and kauri varnish.	Condition good; coating tough and elastic.
Kauri varnish.	Condition good; coating tough and elastic.
Suspected varnish.	Condition good; coating tough and elastic.
Lucol.	Condition good.
First coat red lead, second coat graphite.	Peeled off.
First coat red lead, second coat red oxide.	Peeled off.

TABLE VI. SUMMARY OF TESTS.

PAINT.	LOESNER.	WATER AND MOISTURE.	IMMERSION.	ELECTRICITY.	HEAT.
Dixon.	Attacked.	Attacked.	Slightly attacked.	<300	Not attacked.
Durable metal.	Slightly attacked.	Not attacked.	Slightly attacked.	547	Cracked.
Mineral brown.	Attacked.	Slightly attacked.	Slightly attacked.	{ 633 { 743	Not attacked.
Bessemer.	Attacked.	Very much attacked.	Attacked.	<300	Not attacked.
Raw oil.	Very much attacked.	Very much attacked.	Very much attacked.	—	——
Boiled oil.	Very much attacked.	Very much attacked.	Very much attacked.	<300	——
Black enamel.	Very much attacked.	——	——	<300	Brittle ; peeled off.
Red lead.	Not attacked.	Not attacked.	Not attacked.	{ 1707 { 647	Brittle ; peeled off.
Red lead and lucol.	Attacked.	Not attacked.	Not attacked.*	438	Brittle ; peeled off.
Red lead 30%, White lead 60%.	Slightly attacked.	Not attacked.	Not attacked.	660	Brittle ; peeled off.
First coat red lead, Second coat white lead.	Slightly attacked.	Not attacked.	Not attacked.*	850	Brittle ; peeled off.
Barytes and boiled oil.	Attacked.	Attacked.	Slightly attacked.	560	Peeled off.
Oxide iron.	Attacked.*	Slightly attacked.	Slightly attacked.	<300	Not attacked.
Zinc white.	Somewhat attacked.	Attacked.	Attacked.*	630	Peeled off.
Zinc and barytes.	Attacked.	——	——	697	Not attacked.
White lead and zinc.	Not attacked.	Attacked.	Attacked.*	—	Brittle.
White lead.	Slightly attacked.	Slightly attacked.	Slightly attacked.*	510	Peeled off.
White lead and lucol.	Slightly attacked.	Slightly attacked.	Slightly attacked.	827	Peeled off.
Lead and barytes.	Attacked.	——	Attacked.*	750	Peeled off.
Red lead and graphite.	Slightly attacked.	——	——	573	Peeled off.
Red lead and red oxide.	Slightly attacked.	——	——	917	Peeled off.
Red lead, red oxide and lucol.	Slightly attacked.	——	——	—	——
Rosin varnish.	Very much attacked.	Attacked.	Very much attacked.	540	Peeled off.
Half rosin varnish.	Attacked.	Slightly attacked.	Very much attacked.	395	Not attacked.
Kauri varnish.	Slightly attacked.	Slightly attacked.	Slightly attacked.	395	Not attacked.

* Coating tender.

A comparison of the tests, Table VI, would seem to show that the results obtained by the Loesner test agree well with the "water and moisture" and "immersion in water" tests; these, in turn, agree well with the results obtained in practice. As was to be expected, they do not agree with the results of the heat test.

Considering the various paints themselves, it is evident from these tests that the paints which best withstand the action of water or atmospheric agencies are those which are most attacked by heat, and *vice versa.*

These are, in order of most resistance: Red lead; red and white lead mixed, or first coat red lead and second coat white lead; durable metal coating; white lead; the iron oxide paints, or the above paints mixed with ground barytes. It should, however, be borne in mind, in this connection, that a longer time for drying of the painted strips would have been desirable, but it was impossible to give it. The shortness of time is particularly favorable to the lead paints.

For the most complete protection of iron it would seem to be essential to use a paint in which the pigment combines with the oil, as with the lead paints, or a varnish carrying pigment. These tests well show how inefficient a protection is linseed oil without a pigment.

Three varnishes were tested at the same time, pure kauri, half kauri and half rosin, and pure rosin; their protecting power was in the order here given, the kauri standing the tests the best.

THE HANGING VALLEYS OF GEORGETOWN, COLORADO.

By W. O. CROSBY.

Georgetown is situated in the valley of Clear Creek, a tributary of the South Platte draining the eastern slope of the Main Range in the latitude of Gray's Peak, in the county of Clear Creek, 50 miles by both creek and railroad from Denver, and at an altitude of 8,500 feet. The town lies at the northern foot of Leavenworth Mountain (Figure 1) which, continued above timber line in McClellan Mountain, divides the main stream from the important tributary known as Leavenworth Creek. Below Leavenworth Mountain the trend of the valley is northward for about two miles, between the long, straight ridge of Griffith and Saxon Mountains on the east and the slightly divided Republican, Democrat, and Columbia Mountains on the west, to the foot of Empire Pass, where Columbia Mountain is connected with Douglas Mountain by a low, sharp ridge. At this point a long detrital cone, heading in a prominent gulch on Saxon Mountain, obstructs the drainage across the entire breadth of the valley. Below this obstruction the bottom of the valley is narrow, with little or no level land, and the stream falls rapidly as it winds around the base of one detrital cone after another; but above it, to the upper end of Georgetown and the base of Leavenworth, the valley floor is approximately level for a breadth of 1,000 to nearly 2,000 feet, suggesting the silted-up bed of a temporary lake, above which the mountains rise abruptly 3,000 to 4,500 feet. Up stream the north-south course of this part of the valley is continued in the valley of Leavenworth Creek, between Independence Mountain on the east and Leavenworth Mountain on the west, as far as the beautiful morainal lakelets known as Green Lake ($2\frac{1}{2}$ miles) and Clear Lake (3 miles) and beyond; while Clear Creek, above Georgetown, swings in a graceful curve to its normal westerly course before reaching Silver Plume ($2\frac{1}{2}$ miles) and holds this course to its source in the Snowy Range.

The interest of this paper centers in the relations of these two valleys to that part of the main valley immediately below Leaven-

FIG. 1.—PANORAMIC VIEW OF THE GEORGETOWN VALLEY, SHOWING ITS ABRUPT TERMINATION AGAINST THE NORTHERN FACE OF LEAVENWORTH MOUNTAIN, WITH THE HANGING VALLEY OF LEAVENWORTH CREEK ON THE LEFT AND OF CLEAR CREEK ON THE RIGHT.

worth Mountain and occupied by Georgetown, nearly the entire field of the study being shown in Figure 1. Below the high moraines enclosing Green and Clear Lakes, the valley of Leavenworth Creek is wide and its gradient low, the stream meandering somewhat across its approximately base-levelled floor. As it approaches Georgetown, however, the creek begins to trench the floor of this mature mountain valley and, falling about 700 feet in the last mile, it escapes abruptly into the still broader Georgetown valley, through the deep V-shaped gorge shown in Figure 2, and less distinctly in Figure 1. The general relations of the two valleys are well expressed in Figure 1, which affords an excellent transverse profile of the upper valley and shows it ending abruptly downward in a steep and almost precipitous slope, and thus clearly holding the relation of a hanging valley to the lower valley.

The main problem, of course, lies in the significance of this break between the two valleys; and three general explanations demand consideration — fluvial erosion, glacial erosion, and displacement.

Obviously the floor of the valley of Leavenworth Creek was once continuous with the floor of Clear Creek Valley. The first explanation of the existing discordance, or lack of continuity, would mean that Clear Creek has, in later times, lowered its bed more rapidly than Leavenworth Creek, by virtue, we may suppose, of the advantage which, during the elevation of the range, a main stream would enjoy in experiencing acceleration more promptly than its lateral or right-angled tributaries. This is an important principle, and fully competent, no doubt, to explain many hanging valleys; appearing, for example, to account perfectly for the hanging tributaries of the upper San Joaquin River in California. But the conditions at Georgetown are clearly unfavorable to its application, since the escarpment in which both the valley and gorge of Leavenworth Creek terminate is in the lee of Leavenworth Mountain with reference to the direct and normal course of Clear Creek, and cannot possibly be regarded as due to the erosive action of the latter. The hypothesis of more vigorous glacial erosion in the main valley, appealed to by Davis and others in explanation of some of the hanging valleys of the Alps, and more recently of other districts, is beset by still greater difficulties here; for I have failed to find below Leavenworth Mountain any evidence of glaciation. The mountain slopes are here wholly unglaciated, and all apparent moraines are really detrital cones heading in lateral gulches,

forcing the creek against the base of the opposite slope and thus causing it to meander in spite of its rapid fall. But even granting that the glacier of the Clear Creek Valley did cross the site of Georgetown, the salient northwestern angle or spur of Leavenworth Mountain would prove a still more serious obstruction than before; nor could we appeal with more success to the phenomena of the bergschrund, for surely this basin, a dozen miles from the heads of the valleys in the Snowy Range, was never an amphitheatre of névé; on the contrary, we must think of it as in any case near the lower limit of glaciation and well below the line above which the formation of glacial ice or its firm adhesion to the bounding rocks is possible.

We have next, then, to inquire whether the facts are more favorable to the displacement hypothesis. In this connection some of the vein phenomena of the district are significant. Traversing the lower slope of Griffith Mountain, to the north of Leavenworth Creek, is the Griffith lode, which may be regarded as virtually continuous to the south and southwest with the lode system of the Alaska, Centennial, Burrell, and Big Indian Mines, crossing the mouth of Leavenworth Gulch just below the escarpment and traversing the northern face of Leavenworth Mountain to and through the prominent notch high up on its northwestern spur. The workings of the Centennial Mine, with a depth of 600 feet and a length of over 1,500 feet, extend directly across the mouth of Leavenworth Gulch and reveal perfectly the character of the fissure at this most critical point. Here, as throughout its course, it is an approximately plane, vertical, and vertically striated wall, characterized at most points by a clay gouge from six inches to a foot or more in thickness, and by more or less extensive sheeting of the granitic complex, as well as by frequent oblique breaks, or branch fissures, in which the filling of quartz and ore chiefly occurs. A more ideal fault fissure it would be difficult to imagine; and that the movement has been in part geologically recent is indicated by certain features of the Griffith and neighboring mines to which my attention has been directed by Mr. J. S. Randall, of Georgetown. For a length of a mile or more along the lower slope of the mountain the country rock is in a shattered condition, so that very little continuously solid rock is found, even at a depth of hundreds of feet, the structure being so open at some points as to permit a free circulation of air through

the ground. Undoubtedly the fissure system and the veins antedate the modern escarpment, at least in the main; but that there has been comparatively recent movement along this line is unquestionable; and of this the unlithified selvage, and not uncommon brecciation of the vein contents, with deposition of cryptocrystalline secondary quartz, are evidence.

There is evidence in the vein developments and in the breaks of the northwestern spur of Leavenworth Mountain that the fissure system divides in this mountain, a more northerly branch following and defining the northern base of the mountain and thus determining the abrupt and square southern end of the Georgetown Valley. A fracture system, which might be regarded as either a southward continuation or a repetition of the main Griffith-Centennial line, traverses the eastern slope of Leavenworth Mountain. It is well exposed for study in the extensive workings of the Aliunde Mine, and is seen to be characterized by a dike of porphyry, the geological recency of which is indicated by its broad margins of obsidian. The dike probably postdates the ore development, in the main, but the indications of movement subsequently to the formation of the dike are also very plain; and the downthrow is here quite clearly to the east and not to the west, although still on the side towards the valley. The chief topographic indication of this displacement is found in the dislocation of the tributary valley of Argentine Creek, which thus holds the relation of a hanging valley to the valley of Leavenworth Creek. In this instance the creek has notched its escarpment less deeply and, falling several hundred feet in a small fraction of a mile, develops the water power utilized in the operation of the Aliunde Mine. That the displacement at the foot of Leavenworth Gulch is not measured in its entirety by the height of the escarpment, as shown in Figure 1, is proved by the fact that while the Dewey & Wheeler concentrating mill, which is the point of view for Figure 2, stands on bed rock, which was blasted to prepare the foundation, a shaft about 100 feet from the mill, on the north side of Fourth Street, reached bed rock only at a depth of 125 feet. West of this a second shaft (now filled up) was sunk in 1870, near the corner of Rose and Third Streets in Georgetown, where the surface is approximately 50 feet lower (the first shaft starting on the detrital cone originating in Leavenworth Gulch), and not more than 150 feet from the steep base of Leavenworth Mountain, reaching

bed rock at a depth of 75 feet. Half a mile to the northward, and close against the base of Griffith Mountain, near the mouth of the lower tunnel, a shaft reached bed rock at 60 feet; and a short distance north of this, near the present base of the high dump of the main Griffith Tunnel, and possibly not over 100 feet from the base of the mountain, a well was sunk in early days to a depth of about 100 feet without reaching bed rock.

FIG. 2. — VIEW LOOKING UP THE GORGE OF LEAVENWORTH CREEK.
The sky-line on the right shows, in profile, the original, base-levelled floor of the valley.

In view of these facts, it can hardly be doubted that the part of the valley occupied by Georgetown is a depressed fault block, or graben, and that the valley is due in part to displacement and not wholly to erosion, thus suggesting comparison with Yosemite Valley. This view calls for another and complementary fault along the west side of the valley, at the base of Republican Mountain, and of its existence we have ample evidence, although in this instance the displacement is not close against the mountain. The confluence of the two creeks is not near the foot of Leavenworth Mountain, as would

be most normal, but half a mile or more to the northward; and as a specially interesting and puzzling feature in the topography of Georgetown we have the narrow ridge of granite extending north from the northwestern corner, or spur, of Leavenworth, separating Clear Creek from the level plain on which the main part of the town is built and terminating abruptly in the bold knob on which formerly stood the brick stack of Hall's reduction works. This knob

FIG. 3. — VIEW FROM HALL'S LEDGE LOOKING UP THE VALLEY OF CLEAR CREEK, WITH THE DEVIL'S GATE GORGE IN THE MIDDLE DISTANCE.

The low ridge of granite in the foreground separates the bed of Clear Creek on the right from the relatively low plain on which the main part of Georgetown is built.

or ledge is the point of view for Figure 3, which shows the ridge of granite bordered by the bed of Clear Creek on the right and connecting upward on the left with the angle of Leavenworth Mountain. On the west side of this ridge, which at the lowest points is not more than 5 feet above the creek, the latter actually or practically flows on the bed rock surface, while on the east side the level gravel floor of the valley is 10 or 12 feet, and the bed rock floor 85 or 90 feet, below the level of the creek. Obviously the east side of this ridge is on a fault with the downthrow to the east, run-

ning straight up the north face of Leavenworth Mountain, intersecting the oblique and east-west faults previously described and giving the northwestern angle of the mountain its salient character. The ridge just described, terminating in Hall's Ledge, is clearly only a narrow remnant of the gradually tapering north end of Leavenworth Mountain, which, we may or must believe, once separated the two creeks. Accepting this view, the displacement of the bed rock surface is probably not less than 100 feet; and the most anomalous feature is seen in the fact that the creek is left on the upthrow side for one-third of a mile after entering the Georgetown basin. Sedimentation in this basin has virtually obliterated the fault as a topographic feature of the valley floor and destroyed the water power to which it gave rise. Were the valley cleared of detritus, the part of the valley of Clear Creek above the fault would become a hanging valley in its relation to the Georgetown basin, or graben, or that part of the valley below the fault.

Under existing conditions, however, and in spite of the accumulated detritus below the main fault just described, the floor of this valley is abnormally elevated for a short distance, where it is trenched by the gorge, some 75 feet in depth, known as the Devil's Gate (Figure 3). The part of the valley above the Devil's Gate, which may conveniently be designated the Silver Plume Valley, is, aside from the morainal deposits which terminate half a mile or more above the Devil's Gate, flat-bottomed and free from a gorge down to the beginning of the Devil's Gate, where the rocky floor is abruptly uplifted at least 75 feet. In other words, local movement, or block faulting between two of the fractures crossing the northern face of Leavenworth Mountain, has raised a rock dam across the valley here approximately 75 feet high and 500 to 800 feet broad up and down the valley. Through this dam the stream has cut its gorge; and the absence immediately above this barrier of stratified deposits or any evidence of a lake is a plain indication that the elevation was gradual, and so slow that the stream kept pace with the movement. The former course of Clear Creek across this elevated tract can be traced along the line of the railroad east of the gorge in the waterworn ledges and pot-holes and well-rounded and waterworn gravel and bowlders identical with those of the modern stream bed, in which pot-holes are also forming. Farther up this valley we have similar and equally clear evidence of geologically recent faulting

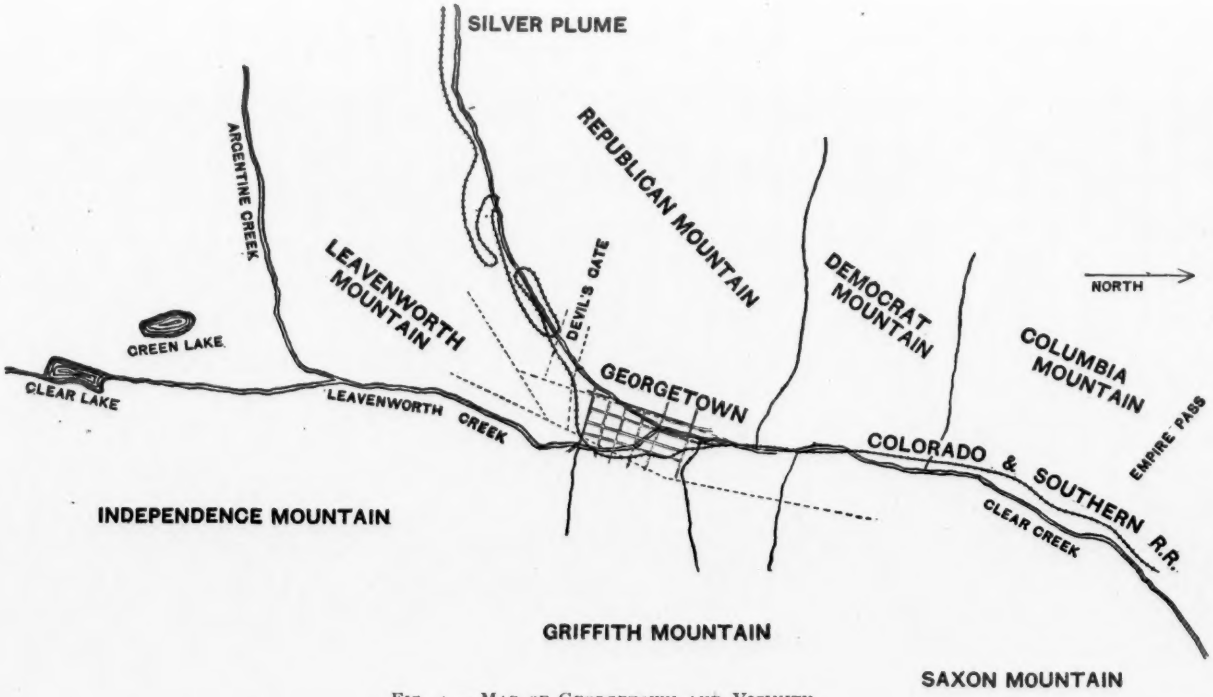


FIG. 4. — MAP OF GEORGETOWN AND VICINITY.

The broken lines show the probable locations of faults defining the Georgetown graben. Scale: one inch = about 4,000 feet.

in the immense semi-detached block of Sherman Mountain, rising precipitously from the north side of the valley between the village of Silver Plume and the group of rich mines, in the workings of which the fault fissures have been extensively and clearly developed and repeat the phenomena of the Aliunde Mines on the eastern slope of Leavenworth Mountain.

Taking a broader view of these phenomena, it appears improbable that they are peculiar to this district, but rather that they are characteristic of many of the drainage systems of the mountains, especially towards the headwaters and the axis of the range. The idea is inevitably suggested that the elevation of this great mountain mass, the broadest and possibly one of the oldest of the Colorado ranges, has been recently, and may be still in progress; and that while in the past the movement has been chiefly massive, developing the magnificent fault scarp overlooking the plains, it has in later times affected the axis more than the margin of the orographic block, leading to a marked tilting of the Cretaceous peneplain represented by the broad, grassy uplands or shoulders (alps) of the mountains; and in part, at least, the uplift is very locally differential and, in the Georgetown instance, in a way to accentuate the topography.

BOOK REVIEWS.

Gas Analysis.

Methods of Gas Analysis. By Dr. Walther Hempel. Translated from the third German edition and considerably enlarged by L. M. Dennis. New York: The Macmillan Co. 1902. Price, $2.25.

This makes practically a fourth edition of Hempel's well known and compendious work upon the subject. Some hundred pages have been added, including new methods of collecting and keeping gas samples, the use of the Orsat and Bunte apparatus, of the determination of combustible gases and the separation of argon from the air. The analysis of acetylene gas, of the gases produced by bacteria, or evolved in the electrolysis of chlorides and in the manufacture of bleaching powder, is detailed quite fully.

Especially valuable additions are the descriptions of an apparatus for the determination of the heating power of small quantities of gas; of a flame calorimeter for the determination of the calorific power of gases by the height of a flame, like the gas works' photometer; of the "gas lantern," an apparatus for controlling gas processes and inspecting heating plants. A chapter has been included upon the volumetric determination of carbon in steel.

In common with many foreign treatises, work done in other countries has been overlooked; one seeks in vain for mention of the work of Campbell and Hart upon the absorption of hydrogen by palladium chloride, or of that of Clowes on the absorption of oxygen by potassium pyrogallate, and of others.

There are, too, several statements and operations which are open to serious question: for example, in the method of sampling gases, an iron tube is used for temperatures above 300°. Moissan and also Fischer have shown that ferric oxide is reduced by carbonic oxide at 350° and higher; when this takes place the analysis would, of course, give an utterly false impression of what is transpiring within

the furnace. A method for the estimation of nitrogen trioxide is given, although according to Lunge and Porschner this gas does not exist. With the Hempel calorimeter, coal is compressed into cylinders for combustion. The statement might have been added that this is impracticable for anthracites and for many samples of American bituminous coals.

The subject of the practical application of gas analysis to chimney gases is dismissed with too little detail. Although the primary object of the book is to describe Hempel's apparatus and methods, an important apparatus like the gas calorimeter of Junkers need not have been omitted.

The index could be enlarged to advantage in this and the German editions. A. H. GILL.

Steam Power Plants, Their Design and Construction. By Henry C. Meyer, Jr. New York: McGraw Publishing Co. 1903. $2.00.

This book is the assemblage and amplification of a series of articles which originally appeared in the *Engineering Record*, and which were written with the idea of giving the purchasers of boilers, engines, and other parts of steam power plants some idea of their problems, whether their problems were approached with the aid of a consulting engineer, or with nothing more than a business man's common sense and general information.

That the author apprehends the dangers and difficulties of the situation is shown by his opening sentence: "No better service can be done the non-expert about to construct a steam plant than to advise him to engage at the outset of the project some capable engineer to design the plant and superintend its installation." If the non-expert will heed this advice, the book cannot do any harm and is likely to do much good. The purchaser will undoubtedly better understand his expert and will be better able to decide on the business side of the transaction, which must, first or last, be decided by the purchaser. There is much, also, that may be profitably read by engineers, and some things that are not usually found in manuals and text-books on engines and boilers.

Another bit of good advice is that the intending purchaser of a small steam outfit shall go to some builder of good repute and, after stating his case, take what is given him; this will include a considerable amount of free expert advice, which in general will be good and not too much biased by the interest of the seller.

After giving such sound advice, one wonders why the author should include tables of dimensions of boilers, proportions of riveted joints, and standard pipe-fittings. These give the information required by the designer of an engine or boiler and not by the purchaser; and the designer has much fuller information than can be included in such a book. It also appears remarkable that our old friend, the formula for the thickness of a thin hollow cylinder, should be credited to the inspection department of the city of Philadelphia. But, after all, this array of technical information may deter the non-expert from entering too lightly into engine and boiler design.

Among the many features to be commended are samples of specifications for engines and boilers and other appliances, together with information concerning the customary way of arranging these matters. A number of minor, and yet important, matters may be noted, for example, that the builder or bidder should be notified if there is a traveling crane or other facility for handling and erecting machinery, in order that he may take account of it in making his bid.

Chapters to be especially commended are those on piping and handling coal; here there is the maximum of common sense with a minimum of expert information, and a business man may readily understand the greater part of the matter presented. In contradistinction, it is difficult to see what such a man can get from the chapter on chimneys, unless it may be the opinion that they are expensive and both difficult and uncertain in design. It is to be regretted that the author did not quote tables of sizes (such as are given by Kent and others) instead of formulæ, which are somewhat difficult to use, and in the hands of the non-expert may lead to absurd results; in the tables such absurdities are carefully omitted. Exception should be taken to the statement that a mechanical stoker can be run by firemen of ordinary intelligence; it is more proper to say that these appliances always work well in the hands of experts sent out by the makers, and frequently fail because they are afterwards run without sufficient intelligence. In the book are a number of illustrations to explain methods and details, and also a number of excellent plates

showing large and well-arranged steam plants, *without* explanation. They are interesting and much can be learned from them without explanation, but it is a question whether they will not be a disappointment to the class for which the book is primarily intended.

Science Abstracts, Physics and Electrical Engineering. London: Feilden Pub. Co. New York: International News Co. Monthly. Subs. $7.50; single section, $4.50 yearly.

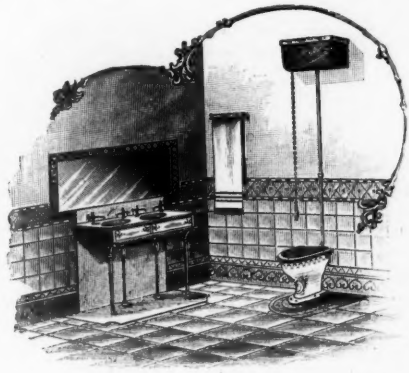
All who are interested in the science of Physics in its various branches, or are concerned with the application of physical principles to engineering problems, know that English "Monatsbericht," *Science Abstracts*, and recognize its value as a source of information in regard to the work being done in this field. The announcement of a change in the plan of publication will be received, therefore, with considerable interest.

This journal was published first in 1895 as a supplement to the Proceedings of the Physical Society of London, under the title, "Abstracts of Physical Papers from Foreign Sources." In 1898, the first volume under the present title was issued, and the scope of the publication was extended to include electrical engineering. It became at that time a partially independent journal, published under the direction of a joint committee from the Institution of Electrical Engineers and the Physical Society of London. The responsible editor is now G. W. de Tunzelman, and the journal is entering upon its sixth year of publication.

It will in future be published in two sections: *Section A*, Physics, embracing light (including photography), heat, sound, electricity and magnetism, chemical physics and electro-chemistry, general physics, meteorology and terrestrial physics, and physical astronomy; and *Section B*, embracing steam plant, gas and oil engines, automobiles, oil engine driven ships and launches, balloons and airships; general electrical engineering, including industrial electro-chemistry, electric generators, motors and transformers, electrical distribution, traction and lighting, and telegraphy and telephony. The subscription price will be eighteen shillings, or four and a half dollars, for each section

separately, including index; for the two sections thirty shillings, or seven and a half dollars.

The American Physical Society is now joined with the Institution of Electrical Engineers and the Physical Society of London in the direction of the publication, and has elected Professor E. H. Hall of Harvard University as its representative on the publishing committee. In consequence of this arrangement, Section A will in future be received by all members of the American Physical Society. The American Institute of Electrical Engineers is also co-operating with the committee and taking special means to bring the publication to the notice of all their members, who will in future be able to obtain it at a reduced subscription rate through the secretary of the American Institute.



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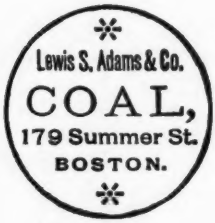

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